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Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

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INTRODUCTION

Oral delivery is the preferred administration route for drugs. Sometimes it can be necessary to employ advanced drug delivery systems to achieve targeted and/or sustained delivery in the gastro-intestinal (GI) tract after oral administration. Micro fabricated drug delivery devices have been proposed as an advanced drug delivery systems being able to increase the oral bioavailability of drugs [Chirra et al., 2012]. Of these micro devices, microcontainers are suggested as especially promising [Chirra et al., 2014]. Primarily, this is due to the fact that the size and shape of the microcontainers can be controlled very precisely and therefore, polydispersity as seen example for micro- and nanoparticles is avoided [Randall et al., 2007]. Microcontainers are polymeric, cylindrical devices in the micrometer size range (Figure 1). A major advantage is that these devices allow for unidirectional release, as only one side of the microcontainers is open compared to microparticles where release can occur over the whole area of the particle [Nielsen et al., 2012], [Nielsen et al., 2014].

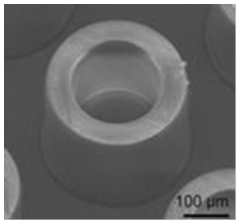

Figure 1: SEM image of a microcontainer

The purpose of these studies was to fabricate microcontainers in either SU-8 or biodegradable poly-L-lactic acid (PLLA), and fill the microcontainers with poorly soluble drugs or vaccine particulates. Furthermore, the application of the microcontainers as an oral drug delivery system was investigated in terms of release, *in situ* intestinal perfusion and oral bioavailability.

EXPERIMENTAL

SU-8 microcontainers were fabricated using lithography, whereas PLLA microcontainers were prepared by hot embossing. In terms of drug filling, the SU-8 microcontainers were filled with polyvinylpyrrolidone (PVP) by inkjet printing followed by supercritical CO_2 impregnation of ketoprofen into the PVP matrix. As an alternative filling method, the powder of amorphous sodium salt of furosemide (ASSF) or cubosomes with ovalbumin were filled into the SU-8 microcontainers. The PLLA microcontainers were filled with drug formulation by embossing the microcontainers into a polycaprolactone (PCL) and furosemide (4:1 w/w) layer.

For the ASSF-filled microcontainers, an enteric-resistant lid of Eudragit L100 was spray coated onto the cavity of the microcontainers. Release of ASSF from the coated microcontainers was investigated using a µ-Diss profiler in simulated intestinal medium at pH 6.5. Closed loop *in situ* intestinal perfusions were performed in rats of the Eudragit-coated ASSF-filled microcontainers and compared to a furosemide solution. The microcontainers were dosed to the small intestine, and at the end of the study, the small intestine was harvested from the rat and imaged under a light microscope. For the *in vivo* studies, the rats were dosed orally with capsules containing ASSF-filled microcontainers coated with Eudragit L100. As control, capsules were filled with the powder of ASSF and the capsules were coated with Eudragit L100.

RESULTS

The SU-8 microcontainers had an inner diameter of 220 µm and a cavity depth of 270 µm (Figure 1), and for the PLLA microcontainers the inner diameter was found to be 240 µm and with a cavity depth of 65 µm (Figure 2).

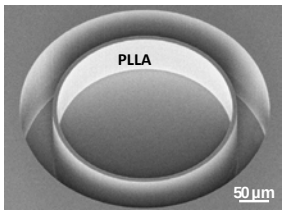

Figure 2: SEM image of a PLLA microcontainer

The microcontainers were successfully filled with either PVP:ketoprofen, PCL:furosemide, cubosomes or ASSF (Figure 3A), and the ASSF-filled microcontainers were coated with a lid of Eudragit L100 (Figure 3B).

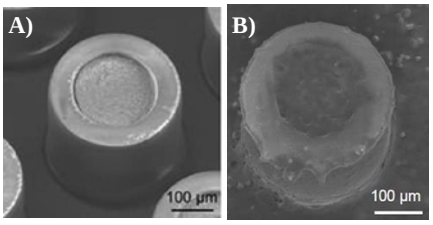

Figure 3: A) SEM image of an ASSF-filled microcontainer B) followed by a coating of Eudragit L100.

A fast release of ASSF from the microcontainers was observed and the Eudragit coating was shown not to be a hindrance for rapid release at intestinal conditions. For the intestinal perfusion studies, the absorption rate constant of ASSF was 1.5 fold higher, when ASSF was confined in the microcontainers compared to a furosemide solution. Micrographs of the small intestine after the perfusion studies showed that the microcontainers interacted with the mucus in the small intestine, and the microcontainers were engulfed by the intestinal mucus (Figure 4). This was also observed for empty microcontainers without drug and coating (Figure 4C)

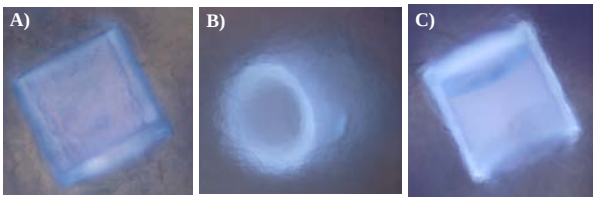

Figure 4: Images of the microcontainers following intestinal perfusion studies. A) and B): Microcontainers filled with ASSF and coated with Eudragit L100. C) Empty microcontainer

The oral bioavailability study showed that the relative oral bioavailability of ASSF in microcontainers was 220±43% when compared to drug-filled capsules coated with Eudragit (Figure 5).

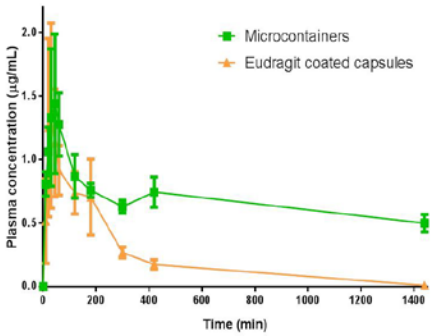

Figure 5: Plasma concentrations of microcontainers filled with ASSF coated with Eudragit L100 and filled into capsules and ASSF dosed in capsules with Eudragit coating after oral dosing to rats.

CONCLUSION

Both SU-8 and biodegradable PLLA microcontainers were successfully fabricated and loaded with drug/formulation. A fast release of ASSF was facilitated from the SU-8 microcontainers. Furthermore, the microcontainers were found to interact with the intestinal mucus resulting in a higher oral bioavailability when compared to non-confined ASSF. The fabricated microcontainers therefore show considerable future potential as oral drug delivery systems.

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